Number	Company	SOW Title	Date	Amount Awarded
N00014-08-C-0324	Advantage Imaging Systems, Inc	"5.B Detailed Statement of Work"	9/9/2008	$4,050,782
N00014-09-C-0305	JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATOR Y	"Statement of Work"	3/31/2009	$876,779
N00014-09-C-0246	TELEDYNE SCIENTIFIC & IMAGING, LLC	"BIOMETRIC CAPTURE AT A DISTANCE STATEMENT OF WORK"	9/30/2009	$2,821,923
N00014-08-C-0396	SPARTA INC.	"AUTOMATED DISMOUNT TAGGING AND TRACKING WITH SPECTRAL IMAGING"	8/26/2008	$511,257
N00014-08-C-0302	Logos Technologies	"NON-PROPRIETARY SEVERABLE STATEMENT OF WORK"	7/22/2008	$671,609
N00014-08-C-0347	General Dynamics Advanced Information Systems	ATTACHMENT NUMBER 1 , "STATEMENT OF WORK"	8/21/2008	$3,474,149
N00014-08-C-0301	Avaak, Inc.	"Multi-modal Agile Sensor Network for GWOT"	7/24/2008	$1,232,641

1.1 NON-PROPRIETARY SEVERABLE STATEMENT OF WORK

1.1.1 Scope

The contractor will develop, build, and test an electro-optic, wide-area, high-resolution persistent surveillance capability suitable for employment on the USMC Tier III UAV (the AAI Shadow 200) and on the Tier II (Heavy) system based on the InSitu ScanEagle UAV system. The development will include the airborne system consisting of a camera and onboard data-capture server and processing system, all constrained by size, weight, and power consistent with the Tier II UAV, and the ground system to receive, exploit, and disseminate data. The contractor will also provide the software, hardware, and interfaces for a utility demonstration of the control, use, and exploitation of the data. At the conclusion of this effort, the contractor shall deliver the prototype modules ready for integration onto a UAV for further experimental and operational testing.

The target capability of the system is to provide a PS capability on UAVs available to expeditionary units exceeding that provided now in manned platforms. The system will have a large field of view (nominally 60°) and high pixel count (nominally >200 million pixels) to enable near-real-time tactical persistent surveillance using small, light-weight systems. The system will provide 10 or more image and video feeds in real time as well as support for limited non-real time and forensic users.

1.1.2 Task 0 – Project Management

The contractor project manager (PM) shall be identified to the government at contract start. The PM is responsible for all scheduling, coordination and reporting activities for the project. The PM shall be the primary interface with government as well as any subcontractors, vendors or suppliers. The project-management task is spread across all phases and years. The products that result from this task are contract start-up actions such as getting subcontractors on contract, refinement of the project goals, quarterly technical and financial reporting, and contract closeout actions and documentation. The metrics that will be met as a result of this task are those specified in the solicitation, the award, and by government-specified formats for reporting.

1.1.2.1.1 Task 0.1 Contract Start – Milestone 0A

Activities under this effort will begin at contract start, or other date as specified in the contract. This milestone is complete at contract start. The products that result from this task are the prime contract award and subcontract awards. The metrics that will be met as a result of this task are as defined in the FARs, DFARS, as tailored by the CO.

1.1.2.1.2 Task 0.2 Contract Kick-off Actions

Kick-off actions include the kick-off meeting with the government contracting officer's technical representative, government subject-matter experts, representatives from major subcontractors and team mates, the PM and contractor task leaders. Activities also include executing necessary subcontracts.

Major subcontracts shall be negotiated and signed within 10 days of contract award. Failing that, daily written reports to the contracting officer will describe progress toward subcontract award completion. Arranging the kick-off meeting to accommodate most of the planned participants will be completed ASAP, and will be scheduled in consultation with the contracting officer's technical representative.

The main purpose of this task is to initiate all aspects of the program, synchronize program activities and to reach a common expectation for progress and results.

This task is complete when the major subcontracts are let, the kickoff meeting is complete and the minutes of the kick-off meeting are published.

The product that results from this task is refinement of the baseline project schedule. The metrics that will be met as a result of this task are as specified by the solicitation and contract award.

1.1.2.1.3 Task 0.3 Quarterly Technical and Financial Reporting

These are the fundamental progress statements for the program. The technical portion of the report shall feature a summary of the technical progress during the quarter for each major task in the current phase. They will also include such new information as bears on the prospects of achieving the program goals. Financial reports will indicate the funds spent up to the end of the previous reporting period and projections including next quarter and EAC of the current award period. The metrics that will be met as a result of this task are as specified by the solicitation and contract award.

1.1.2.1.4 Task 0.4 Contract Closeout

Closing the contract involves activities such as submitting the final report and other deliverables, and submitting the final invoice. The metrics that will be met as a result of this task are as specified by the solicitation and contract award.

1.1.3 Task 1 (Phase 1) System Preliminary Design (FY-2008)

The contractor shall carry out all design activities consistent with achieving the goal of providing the LEAPS capability on a Tier II UAV. This includes the full range of design on all aspects of the system. Activities in this phase are separated into tasks described below.

Successful system design relies on coordination and on maintaining a size, weight, power, and financial budget. The primary system risks shall be addressed in this phase. The primary technical risk is in meeting the weight limits for the UAV. The contractor shall create and maintain an interface control document between and among the several components of this system.

The output of this phase is a PDR-level system design suitable to an R&D effort. The PDR criterion shall be sufficient design fidelity to convince a "knowledgeable skeptic" that the system will probably work and can be completed within the resources budgeted to the effort.

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The products that result from this task are the preliminary requirements report and the preliminary design review. The metrics that will be met as a result of this task are those specified in this offer.

This phase is complete when the PDR has been approved.

1.1.3.1 Task 1.1 System Architecture Preliminary Design

The contractor shall develop a system architecture for this program. Key features include component (and subcomponent where appropriate) definition, functions, interfaces; and size, weight and power budgets.

The system architecture shall be informed by interaction with government subject-matter experts to enhance the system utility for tactical intelligence. A preliminary CONOPS shall be developed that emphasizes the tactical utility of LEAPS and de-emphasizes the strategic and forensic uses of LEAPS.

This is the primary performance predictor of the eventual LEAPS system and must be dynamic in that it shall be updated to reflect design changes and refinements. Engineering trades suggested in one component that affects other components will be tracked through the system architecture.

The system architecture shall be developed in the context of existing and emerging DoD systems with the objective of seamlessly integrating the demonstrated capability into existing systems where advantageous. The interface, control and exploitation software is mostly application specific. Maximum use shall be made of pre-existing software elements whenever possible.

The output of this task is a living system architecture document that maintains rational interfaces between components during the give-and-take design process without losing sight of the eventual use of the system. Component performance metrics shall be provided to track system performance at later program stages.

1.1.3.2 Task 1.2 Preliminary Requirements Report

The contractor shall prepare a preliminary requirements report (PRR) to include anticipated requirements to be met in the PDR and CDR respectively. This includes preparation of the document and internal reviews for consistency and quality. The PRR shall be delivered to the COR and PM on or about Month 3. This task results in the production of the PRR document. This task, which constitutes Milestone 1A, is complete upon submission of the Report.

The product that results from this task is the preliminary requirements report. The metrics that will be met as a result of this task shall be as specified by the contractor.

1.1.3.3 Task 1.3 Air System Preliminary Design

The contractor shall design all parts and subcomponents for the aircraft except that the camera mount may be specified and provided by the government. This will consist, at a minimum, of

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the focal-plane array integrated into a camera, data capture electronics, archive and communication protocols.

The design shall include operational software, communication strategy, isolation and pointing, and be able to receive, process, and respond to data request from any of the several forward users as well as the main ground control station. The communication link is specified as the common data link (CDL) and is provided as an aircraft service.

The air system design shall be compatible with all aircraft constraints and fulfill the system architecture goals for expandability. Component performance metrics shall be provided to track system performance at later program stages.

The product that results from this task is the preliminary design review. The metrics that will be met as a result of this task shall be as specified by the PRR.

This task is complete when the PDR has been approved.

1.1.3.4 Task 1.4 Ground Station Preliminary Design

The ground station is the control and primary user station for the system and is located at the combat operations center. It is composed of the necessary displays, user interface, data storage, analysis software, and exploitation algorithms.

The main function of the ground station is to obtain the most relevant data of that available. This may be accomplished through aircraft control as well as via innovative camera controls or data retrieval.

The output of this task is a self-consistent design for the hardware and software necessary to control the aircraft, payload and data download. Component performance metrics shall be provided to track system performance at later program stages.

The product that results from this task is the preliminary design review. The metrics that will be met as a result of this task shall be as specified by the PRR.

This task is complete when the PDR has been approved.

1.1.3.5 Task 1.5 Preliminary Design Review (PDR)

The contractor shall prepare for the preliminary design review. This includes preparation of the presentation materials and internal reviews for consistency and quality. The PDR shall be scheduled at the convenience of the COR, approximately the end of Month 9.

The contractor shall host a meeting for the purpose of presenting the preliminary design review. The venue shall be large enough to accommodate all interested parties. A fundamental purpose of the PDR is to motivate and request release of funds for the purchase of long-lead items. Toward this end, the contractor must show sufficient design fidelity to fully specify necessary long-lead items.

[redacted]

This task results in the production of the PDR document and all preparations for the PDR meeting itself. This task, which comprises Milestone 1B, is complete at PDR. The metrics that will be met as a result of this task are as established by the contractor.

1.1.4 Task 2.0 (Phase 2) System Critical Design, Component Fabrication, and Component Test (FY-2009)

1.1.4.1 Task 2.1 (Phase 2A) System Critical Design

This task results in the system design validated against operational requirements, design and instructions for all system components, the production of a final system architecture document, the CDR documents and all preparations for the CDR meeting itself.

1.1.4.2 Task 2.2 Critical Design Review (CDR)

The contractor shall prepare for the critical design review. This includes preparation of the presentation materials and internal component CDRs for consistency and quality.

The CDR shall be scheduled for Month 13.

The contractor shall host a meeting for the purpose of presenting the critical design review. The venue shall be large enough to accommodate all interested parties. The product is the CDR document. This task is complete when the meeting adjourns and the minutes are published. This task is complete as Milestone 2A when the CDR has been approved.

1.1.4.3 Task 2.3 (Phase 2B) Component Fabrication and Test Plan

The contractor shall develop (acquire and fabricate) the components of the LEAPS system – including hardware and software. The major components are the air and ground assemblies including operational software. Each of the components shall be consistent with the system architecture and the performance metrics as defined at CDR.

The contractor shall perform component integration, the results of which may result in small changes to the system architecture. If performance metrics exceed CDR levels, the resulting design margin may be allocated to underperforming areas in order to assure a successful final integration.

This is the most complex portion of the system build and the most critical to the military utility of the LEAPS system. Much of this hardware is custom built and tightly integrated in order to meet the size, weight, and power limit for the Tier II UAV.

1.1.4.4 Task 2.4 Component Test Plan Review

The contractor shall prepare and present to the government, the test plan for component testing before proceeding to the component-testing phase. This component test plan review (CTPR) is Milestone 2B.

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1.1.5 Task 3.0 (Phase 3) System Integration and Testing (FY-2010)

1.1.5.1 Task 3.1 (Phase 2C) Component Testing

The products of this phase are the completed and tested individual components of the LEAPS system ready to enter system integration. The metrics shall be as specified in the CDR and PRR.

The measured performance of the components may either yield or consume margin in the design. It is important to re-optimize the system architecture to get a realistic expectation of the integrated system performance in the following phase.

The contractor shall carry out a comprehensive review of all acquisition, fabrication, test and evaluation activities for each component of the LEAPS system.

The intent is to demonstrate adequate performance of each component and motivate entry into the third phase of the program.

1.1.5.2 Task 3.2 System Integration and Test

The product of this task is an integrated system assembly with all necessary subcomponents installed and ready for the flight readiness review (FRR). The completion of fabrication and assembly of some components, when necessary, also is included in this phase.

The contractor shall complete the assembly of the LEAPS system and perform detailed lab tests to demonstrate the combined performance of the assembled components. Key to these tests is to verify image transfer, data request service and system latency. Fundamental to this phase is image quality, geo-location, local reference and user validation. Surrogate data links are permitted for data transfer in place of the partial-CDL radio that will be provided with the aircraft. The communication protocol for the CDL is TCP/IP hence; the surrogate data link shall utilize that standard for consistency and eventual compatibility. The data throughput of the surrogate system shall be limited to 2 Mb/s to accurately simulate the performance of the eventual system.

The product from this task is a working, interacting LEAPS system passing all the lab tests and bench-top performance criteria determined at CDR.

At the conclusion of this phase the LEAPS system will be ready for UAV integration and flight tests to possibly include expeditionary mission support.

This phase is complete when the system satisfies the metrics from CDR and conforms to the aircraft interface control document.

The contractor shall perform EMI testing sufficient to demonstrate that the LEAPS system will not unacceptably impede the performance of the Tier II aircraft. Multiple electronic systems will be contained in a small volume and have the potential to interact in a negative way. Also, the aircraft both generates EMI and is subject to EMI. The ground station will be comprised of mostly off-the-shelf electronics which will come with EMI/RFI certification. System EMI testing will be limited to the air system.

The product from this task is an EMI report.

The contractor shall perform testing for operation and survival in a vibration and thermal environment representative of the UAV operational profile.

The LEAPS system is a first-article prototype and environmental testing is for the purpose of validating the expectation of success in future flight tests rather than to test to destruction.

1.1.5.3 Task 3.3 Operational Utility Assessment Planning

The contractor shall develop a test plan for the assessment of the operational utility of the LEAPS system. The contractor shall seek input from USMC commanders to finalize the concept of operations, and to build use cases upon which the operational assessment will be based. ONR shall provide USMC subject matter experts to provide insight into operational utility for expeditionary warfare and to help plan the airborne data collect for operational relevance.

1.1.5.4 Task 3.4 Flight Readiness Review (FRR) Preparation

The contractor shall prepare for a FRR to determine that the integrated LEAPS is sufficiently mature to be integrated with the surrogate aircraft for flight testing.

1.1.5.5 Task 3.5 Flight Readiness Review (FRR)

The contractor shall conduct the FRR specified in the previous task. The completion of the FRR constitutes Milestone 3.

1.1.6 Task 4.0 (Phase 4) Operational Utility Assessment and Flight Test

The product that results from this task is flight-test data. The metrics that will be met as a result of this task are those established in the FRR-preparation task.

1.1.6.1 Task 4.1 Secure Test Range

The contractor shall assist ONR in securing range facilities appropriate to conducting an operational utility assessment for LEAPS. The product that results from this task is an approved range schedule and support plan. The metrics that will be met as a result of this task are government approval of the range schedule.

1.1.6.2 Task 4.2 Develop OUA Metrics and Test Plans

The contractor shall develop the metrics and test plan that will be used to determine the operational utility of LEAPS.

1.1.6.3 Task 4.3 Secure Surrogate UAV

ONR and the contractor shall secure a surrogate UAV to be used to collect airborne LEAPS data that will be used for the operational utility assessment. The product that results from this task is an approved commitment for the flight-test platform. The metrics that will be met as a result of this task are as specified by the government.

1.1.6.4 Task 4.4 Aircraft Integration and ground Check-Out

The contractor shall integrate the LEAPS system with the surrogate platform and perform ground checks to reduce risk of in-flight system failures. The product that results from this task is a LEAPS system that is integrated with the test platform. The metrics that will be met as a result of this task are as specified by the government.

1.1.6.5 Task 4.5 Test Readiness Review

Following aircraft integration and ground check-out, the contractor shall conduct for ONR, a test readiness review to determine that the integrated system has a reasonably high probability of in-flight performance that meets or exceeds the goals established earlier in the program. The metrics that will be met as a result of this task are government approval of the review and approval to proceed to the next task.

1.1.6.6 Task 4.6 Surrogate UAV System Testing (period 1)

The contractor shall perform airborne data-collection tests using a surrogate UAV to examine the key features that enable operational utility including wide-area, high-resolution airborne imagery, near-real-time image delivery, and responding to specific requests by the "forward commander." The products that result from this task are test data. The metrics that will be met as a result of this task are as specified by the government-approved test plan.

1.1.6.7 Task 4.7 Surrogate UAV System Testing (period 2)

The contractor shall perform airborne data-collection tests using a surrogate UAV to examine the key features that enable operational utility including wide-area, high-resolution airborne imagery, near-real-time image delivery, and responding to specific requests by the "forward commander." The products that result from this task are test data. The metrics that will be met as a result of this task are as specified by the government-approved test plan.

1.1.6.8 Task 4.8 Test Data Analysis

Following LEAPS flight testing, the contractor shall analyze the imagery and other test data, compare them to projected results, and estimate the expected operational utility of the LEAPS system. The products that result from this task are data that respond to the operational utility analysis metrics.

1.1.6.9 Task 4.9 Final Report Preparation

The contractor shall prepare a final report of all phases of the project including the operational utility analysis. The final report shall also provide recommendations for future LEAPS activities including a plan to transition to an interested government program office to become a program of record. Contractor format is acceptable.

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1.1.6.10 Task 4.10 Final Report Delivery

This task and the project are complete upon submission of the report which constitutes Milestone 4. The product that results from this task is government-acknowledged delivery of the final report.

1.1.7 Deliverables

The contractor shall submit all reports, data and deliverables to the ONR designated point of contact for inspection and acceptance.

1.1.8 Security Requirements:

All work performed on this program will be at the UNCLASSIFIED level. Clearance will not be required for program personnel.

1.1.9 Government Furnished Equipment (GFE) / Information (GFI)

The Government will furnish range access and support as needed for the system operational utility assessment at either 29 Palms or Quantico training facilities. This will include: test range time and facility access for two weeks.

1.1.10 Travel

To the maximum possible extent, tasks shall be accomplished by electronic media over existing high bandwidth or other communication links rather than by contractor travel. Travel between contractor facilities and Government facilities at 29 Palms, and/or Quantico, VA, and select other Government locations will be required.

Section 3.2 – Statement of Work (Severable Section)

The development of the first generation stand alone spectral imager prototype tailored for automated dismount tagging and tracking will be performed in a series of ten (10) Tasks with 27 Subtasks to be performed over the first year of the proposed effort, which includes the six month Base Period. Experimentation will be carried out at SPARTA in Arlington, Virginia and the computer system development will be carried out at SPARTA in Centreville, Virginia. Demonstration efforts will be performed both at SPARTA facilities and at Government facilities to be determined at a later time. The Tasks and Subtasks are described below, detailing the objective of the Task and providing a brief explanation of the work to be performed and any product that results from the Task/Subtask, including metrics that results from the Task/Subtask. Operational Utility assessment events are also highlighted as applicable.

The proposed effort is designed to demonstrate function and utility of automated skin detection. SPARTA will provide interface specifications describing optical, electronic and processing requirements (e.g. spectral bands, spectral bandwidth, signal to noise ratio, etc) necessary to apply algorithms that enable automated skin detection. The specifications will be designed to allow Programs of Record to modify existing sensor systems or procure new sensor systems with the necessary capabilities to perform automated dismount detection via spectral skin sensing.

The proposed effort is structured in three Phases, with a six month Base Period followed by two 1-Year Option Periods, each mapped to Government Fiscal Years 2008, 2009 and 2010 respectively. During the Base Period, prototype components will be acquired and the miniature computer to be used in the stand-alone system will be assembled. Assembly and demosntration of the stand-alone prototype, followed by testing in relevant environments will occur in the first Option Period, followed by Sensor Production in the second Option Period.

The Tasks and Subtasks below are numbered according to the project phase during which they will be performed. Tasks performed or initiated in the Base Period will be numbered 1.X or 1.X.X, where as Tasks performed or initiated in the Option Periods will be numbered 2.X for phase 2 (Option Period 1) and 3.X for the phase 3 (Option Period 2).

Phase 1 (Base Period): Prototype Development

Task 1.1. Finalize Prototype Design – The primary goal of this effort is to refine and nail down the design of the prototype to be built, tested and demonstrated in Year 1. SPARTA will apply the experience it gains on its current contract to build a 3 focal plane array spectral imager with an external processor, so this Task should be complete within the first month Year 1. SPARTA will prepare to reconfigure its miniature PATHWAY Phase 2B computer to be able to take input from three CCD sensor arrays, apply the skin detection algorithm and provide a data stream of actionable information. The optical component configuration will use a prism based beam splitter to project a common scene onto three CCD sensor arrays. The purpose of this Task is to confirm the components and materials required for the prototype and identify any potential hang-ups. A detailed process of identifying sensor specifications and requirements and confirming the components and overall design are consistent with meeting those requirements.

1.1.1 Optical Component Configuration – Review the prism based beam splitter design and apply lessons learned from experience with camera system developed under prior effort

1.1.2 Sensor Assessment – Perform detailed calculations of light levels reaching each pixel of the 3 sensor focal plane arrays and identify which available sensors have properties to best

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exploit the expected signal levels. Identify sensors with appropriate interface to enable high data throughput

1.1.3 Processor Assessment – Identify the required components to enable interface with 3 CCD sensor arrays, perform image processing and communicate output. Perform power consumption estimates based on large data processing requirements. Detail processor architecture to meet current system performance requirements as well as facilitate future development cycles

1.1.4 Communication Assessment – Define appropriate communication and user interface for camera system

Task 1.2. Component Acquisition – The objective of this Task is to coordinate with vendors for required components and make purchase orders for all parts to be used in prototype development, including the prism based beam splitter and filter assembly, focal plane array sensors, alignment of sensors, and computer components. To initiate testing as early as possible in the program, SPARTA will purchase components to build two prototype systems. One prototype system will initially be configured with an external processor and will be used for testing and demonstration purposes early on in the effort. The second will be dedicated to the configuration of the miniature computer to be integrated into the stand alone prototype. Once the stand alone prototype is assembled, a second miniature computer will be integrated into the other camera system, resulting in two fully functional stand alone prototypes.

1.2.1 Request and Receive Price and Lead Time Quotes (non-catalog items) – Coordinate with potential vendors to get cost and lead time information for components listed above.

1.2.2 Place Purchase Orders for Components – Formally place orders for components

Task 1.3. Algorithm Refinement – Work performed on this Task will focus on further testing and development of the automated dismount detection algorithms. Specifically, methods to increase true positive rates and decrease false alarm rates in arbitrary lighting will be considered, as well as mathematical implementation methods to increase processing speed. The algorithms will be tested using data from a spectral imaging system similar to the one to be built in this project.

1.3.1 Skin Region Detection and Segmentation – Develop alternative skin detection methods to potentially improve performance in widely varied lighting conditions. Develop methods to automatically segment regions in an image that contain skin and associate regions to specific individuals (i.e. correlating three regions to be the face and two hands of one individual versus three individuals). Develop methods to implement algorithms using fixed point operations to increase data processing rates.

1.3.2 Data Collection – Gather spectral image data in a variety of environments and lighting conditions (e.g. indoors with controlled lighting, outdoors in direct sunlight, outdoors in shadow, outdoors with overcast skies, outdoors with widely varying lighting on partly cloudy days). The data collection will be performed initially with SPARTA's spectral imaging system to enable data collection at the start of the program, and subsequently with the camera systems developed in the effort. The data will include sequences of spectral images. Specifically, imagery at three narrow spectral bands will collected of a scene in rapid succession. The data will be used for algorithm development and false alarm testing. Ground truth of the data collection will be recorded using a digital camcorder collocated with the spectral imager to gather a color video recording of the scene.

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1.3.3 False Alarm Assessment – To quantitatively assess the probability of detection (Pd) and probability of false alarm (Pfa) of the algorithms used for automated skin detection, the data gathered in Subtask 3.2 will be measured against ground truth. The assessment will be performed on a pixel-by-pixel basis, tabulating the number of pixels in each image contain skin and how many are/are not classified as skin, and how many pixels that do not contain skin are classified as such. Receiver operator characteristic (ROC) curves for each algorithm under consideration will be produced as Pd versus Pfa is plotted as the threshold for skin detection is systematically varied.

Assessment Event 1.3.1 – Quantitative Comparison of Skin Detection Algorithms: One of the requirements of this Task is to identify which skin detection algorithms provide the highest detection rates, lowest false alarm rates and are not too computationally intensive. Approximately $2/3^{rds}$ through this task, a series of blind tests will be applied to the algorithms under consideration to quantitatively identify which best meet operational requirements. These tests are the focus of this Assessment Event.

Task 1.4 – On-board Processor Development – The primary goal of this effort is to customize SPARTA's PATHWAY Phase 2B miniature computer to accept input from three CCD focal plane array sensors. To achieve this goal, SPARTA will follow its development plan used on prior efforts, in which the components are assembled on a breadboard to ensure functionality before hard wiring them into a compact board. Successful completion of this Task will be achieved with the completion of a fully functional miniature computer that can be integrated into the camera system. Metrics used to evaluate function include successful communication with, and control of, multiple CCD focal plane array sensors.

1.4.1 Hardware Design – SPARTA will apply lessons learned from its development of a spectral imager with three CCD sensor arrays interfaced with an external computer to apply the automated skin detection in real time to finalize the design of the miniature computer to be used as the onboard processor of the prototype sensor. The objective of this Subtask is to identify the components and architecture required to handle data coming from three CCD sensor arrays, each nominally passing 1392X1040 12-bit data at 20 to 30 frames per second. The primary result of this Subtask is the detailed design of the on-board processor.

1.4.2 FPGA Coding – The objective of this Subtask is to push as much of the automated skin detection algorithm onto the field-programmable gate array (FPGA) to reduce the need to pass all of the data all the way to the CPU. To increase processing speed, fixed point processing will be used, meaning the algorithms will be restructured to use fixed point calculations. The main results of this Subtask include demonstration of successful interface between the CCD sensor arrays and the FPGA and the successful implementation of the image processing algorithms used for automated skin detection.

1.4.3 CPU OS setup (likely Linux) – The objective of this Subtask is to install an operating system onto the main CPU of the miniature computer. The result of this Subtask will be a functional computer that recognizes the other components of the on-board processor (FPGA, memory buffer, RAM, Flash memory for bootup and external communication line, likely a gigabyte Ethernet line). The CPU will be able to be controlled with an external PC for development and testing.

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1.4.4 Application Development (for comm w/ PC) – Once the components are successfully assembled, the software used to effectively deliver the skin detection information will be implemented. The main objective of this Subtask is to demonstrate control/synchronization of the CCD sensor arrays, full functionality of the algorithms to be used for skin detection and output of relevant data. The primary result will be a demonstration of these capabilities on a breadboard (pre-assembled) version of the miniature computer.

Assessment Event 1.4.1 – Sensor Interface: Before full camera control can be demonstrated, the ability for the components of the miniature computer, in particular the FPGA, must be able to interface with the CCD focal plane array sensor. This assessment event represents the initial tests and demonstration to interface the components, marking a key system capability since it demonstrates the ability to successfully interface with what will be the on-board processor.

Task 1.5 – Camera System Testing and Dismount Detection and Tracking Demonstration – The objective of this Task is to demonstrate the ability to detect and track multiple dismounts in the camera system's field of view. To that end, the camera system will initially be interfaced with an external computer processor to enable testing right away. The functionality of the system will be tested incrementally. First, the ability to collect and process images from the three CCD focal plane array sensors simultaneously will be tested. Second, application of the automated skin detection algorithms developed in Task 3 and a comparison of true positive rates and false positive rates with SPARTA's experimental breadboard prototype will be performed. Third, segmentation algorithms used to identify the number of individuals in the camera's field of view will be applied and tested. Fourth, multi-target tracking algorithms that use the output from the sensor (position, extent and velocity) will be applied to track each skin region. With the functionality in placed (and tested/reported throughout), the demonstration of detection and tracking of dismounts will be performed in various environments.

1.5.1 Algorithm Functionality Testing – Implementation of the algorithms developed to detect and segment regions in imagery that contain skin will be tested. The ability to continuously detect and associate segmented skin regions with each individual in a scene will be tested. The algorithm tests performed here differ from those performed in Subtask 3.3 in that Pd and Pfa will be performed as a function of individuals in the scene as a function of number of frames (versus the pixelwise assessment in still images performed in 3.3).

1.5.2 Detection and Tracking of <5 Dismounts – Multi-target tracking algorithms will be applied to the output data stream from the spectral imaging sensor. The main objective of this Subtask is to demonstrate the ability to initiate and maintain tracks on less than 5 individuals in the camera system's field of view as they move throughout (and into and out of sight within) the scene. The Subtask represents an incremental step in camera functionality and utility. Testing will occur initially in and around SPARTA's offices in Arlington, Virginia. The full demonstration is expected to take place at Government facilities.

Assessment Event 1.5.1 – Functionality Test in Variety of Operating Conditions: The performance of the camera system operating with external processor will be assessed at this event. Specifically, the ability to detect dismounted personnel in a variety of lighting conditions will be considered, including , outdoors in direct sunlight, outdoors in shadow, outdoors with overcast skies, outdoors with widely varying lighting on partly cloudy days. The probability of detection (Pd) and false alarm (Pfa) for detection of skin will be used to quantify the performance.

[redacted]

Task 1.6 – Cueing of High Resolution Sensor – The objective of this Task is to introduce the ability to extract actionable data from the prototype under development to demonstrate its utility. This will be performed by using the output of the prototype sensor to cue a high resolution sensor to dwell on an individual in the prototype's field of view as the individual moves around. The high resolution sensor will be relatively straight forward, such as a camera with a zoom lens or laser pointer, and will be positioned on a gimbal mount. A demonstration of the ability to successfully dwell on a target of interest will be the result of this Task, measured against a duty cycle of maintaining an accurate track on the individual as a function of his/her speed.

1.6.1 Demonstrate Ability to Choose Track of Interest – The output from the camera system will be data used to form tracks on individuals in its field of view. The objective of this Subtask is to enable the operator to visualize the tracks and choose one of interest. For example, a scene may have four individuals and the software will arbitrarily highlight one of the tracks. The operator can scroll through the different tracks (potentially using the tab key, for instance) to select the track of interest.

1.6.2 Co-Registration of High-Res Sensor and HSI Sensor – To address the desired capability to cue a high resolution pan/tilt/zoom camera (with nominally a 20X optical zoom lens or more) to identify objects of interest, the camera system will be interfaced with a high resolution sensor. The high resolution sensor will be mounted on a gimbal mount to enable panning and tilting as needed to track an individual. The spectral imager under development and the high resolution sensor will be co-registered for multiple operating ranges, including scale preservation to handle any lens distortion.

Assessment Event 1.6.1 – Track Choice Test: The ability for the operator to choose one of potentially several dismounted personnel tracks will be tested here. The assessment event will document the functional requirement to select the track of interest and maintain a track on the individual of interest.

Task 1.10 – Program Management – The objectives of the Program Manager of this effort are to lead the technical development effort and be a direct liaison between SPARTA and ONR and the U.S. Navy. He will directly monitor technical progress and costs, coordinate personnel and maintain continuous contact with Mr. Martin Kruger. He will identify issues as they arise, develop mitigation strategies for them and communicate them to ONR as soon as possible. The result of successful Program Management will be an effective technology development effort under which clear milestones are met and ONR is always well informed on all aspects of the project.

1.10.1 Oversee Technical Progress – The objective of this Subtask is to coordinate the technical development of the proposed effort, by 1.) Working directly with ONR to make sure project plan is understood and agreed upon by all parties; 2.) Coordinating staff with the most relevant experience levels to perform highly technical Tasks; 3.) Providing all those who work on the program a detailed description the specific Task(s) on which they will work as well as a description of how those Tasks fit in with the overall program; 3.) Performing Operational Utility Assessment Events to document technical progress throughout the effort, and 4.) Ensuring all major Milestones are met.

1.10.2 Reporting – The objective of this Subtask is to prepare and deliver all reports of the proposed effort. The list of reports to be delivered over Year 1 of the proposed effort include 1.) Final Prototype Design delivered at a CDR near the beginning of the effort; 2.) Monthly reports

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which detail the technical progress over the previous month, listing the objectives of the upcoming month, any technical or programmatic issues and costs; 3.) Operational Utility Assessment Event reports, which detail the objective, protocol and results of assessment events and demonstrations throughout the program; 4.) Milestone achievement reports, which describe the Milestone, when it was achieved and how achievement was assessed; 5.) Final Technical Report, which details the overall assessment of the prototype system; and 6.) Revised Project Plan for Years 2 and 3 of the proposed effort.

Phase 2 (Option 1) – Testing and Integration in Relevant Environment – Following the successful demonstration of functional and operational utility of the spectral imaging sensor developed in Year 1 of the proposed effort, the transition of the technology to a fully integrated system will begin in Year 2. The integration effort will be based on findings in Year 1 that identify the best application(s) and platform(s) to use/deploy the proposed sensor.

Task 2.4 – On-board Processor Development: Continuation of Task 1.4 (described above)

2.4.5 Assembly – The objective of this Subtask is to configure the components developed and tested in previous Subtasks onto a compact board. The resultant device will serve as the on-board processor for the prototype sensor.

Assessment Event 2.4.2 – Functional Miniature Computer: Once the interface and control of the three CCD focal plane array sensors with the breadboard version of the miniature computer has been demonstrated, the next objective is to demonstrate full camera system functionality via the miniaturized version of the computer.

Task 2.5 – Camera System Testing and Dismount Detection and Tracking Demonstration: Continuation of Task 1.5 (described above)

2.5.3 Detection and Tracking 5+ Dismounts – Following the demonstrated success of Subtask 1.5.2, the camera system will be used to spectrally tag and maintain tracks on 5 or more individuals. The spectral imager will pass data regarding the position and extent of regions in each image that contain skin, and that data will be processed by another computer to maintain tracks. The requirements of central hubs to netted sensors to maintain tracks on a large number of people will be assessed in this Subtask. The demonstration is expected to take place at Government facilities.

Task 2.6 – Cueing of High Resolution Sensor: Continuation of Task 1.6 (described above)

2.6.3 Pointing of High-Res Sensor – The objective of this Subtask is to accurately point the pan/tilt/zoom high resolution camera. Initial efforts will be to assume a fixed operating range, followed by preliminary of ranging estimates of targets based on a the spectral imager being fixed and that dismounted personnel remain on the ground. Successful co-registration will be met when all pixels of the spectral imager can be pointed to within 1/10th the high resolution imager's field of view.

2.6.4 Demonstration of High-Res Sensor Cueing – The objective of this Subtask is to demonstrate the ability to successfully use the spectral imager to cue a pan/tilt/zoom camera to persistently track an individual as he moves through the spectral imager's field of view. This will be achieved by integrating the tracking function with the high resolution sensor pointing capability. The result of this Subtask is a demonstration of operational utility, which will be met by successfully maintaining a track on an individual as he moves through the spectral imager's field of view.

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Assessment Event 2.6.2 – Co-Registration Test: The output from the spectral imager will be used to cue a high resolution sensor. This assessment event is designed to test the registration of the high resolution sensor with regards to the spectral imager. Specifically, each pixel of the spectral image will be mapped to a pointing angle of the high resolution sensor as a function of range. The quality of co-registration will be recorded as a function of high-resolution sensor field of view.

Task 2.7 – Integration of On-board Processor into Camera System – The objective of this Task is to integrate the miniature computer/on-board processor within the housing of the camera system. The result of the Task is a fully functional, stand alone hyperspectral imaging camera that enables automated detection of personnel at video rates. Success will be recognized via the demonstrated communication of the processor with multiple focal plane arrays, application of skin detection algorithms, and offloading of actionable information (i.e. position of dismounted personnel to be used for tracking and cueing of a high-resolution sensor).

2.7.1 Power Supply Configuration – The objective of this Subtask is to incorporate the power supply to the stand alone camera system. Earlier Tasks in the effort will identify the required power for the system, and the corresponding supply will be integrated into the system.

2.7.2 Installation in Camera Housing – All components of the spectral imaging system, including the prism beam splitter, narrow band filters and three CCD focal plane array sensors, on-board processor, communication port and power supply will be assembled within a single camera housing frame. The primary result of this Subtask is a self-contained functional prototype spectral imager tailored to automatically detect skin.

2.7.3 Testing – The objective of this Subtask is to make sure the stand alone spectral imaging prototype has the same functionality as the system with external processor. Camera control (synchronization of image capture from the 3 focal plane arrays; data transfer to FPGA), image processing (application of automated skin classification algorithms), and communications of output will all be tested. The main result of this Subtask is a performance assessment comparing functionality of the prototype with the breadboard system with regards to the rate of collecting, processing and delivering information.

Assessment Event 2.7.1 – See Assessment Event 2.4.2

Task 2.8 – Functional and Utility Demonstration Effort – The objective of this Task is to demonstrate both the functionality and utility of camera system in relevant environments, such as cluttered urban and/or rural settings. Functionality will be demonstrated by viewing the camera system's output via video feed showing automated dismount detection with high confidence (tested against the required true positive rate of >95% and false positive rate of <5%). Utility will be demonstrated by using the actionable data from the camera system to cue a high resolution sensor. Success will be met by having an operator look at the video output from the camera, choose an individual of interest, and have the high resolution sensor automatically maintain a track on that individual as he/she moves through the camera's field of view. The demonstration efforts are expected to be performed at Government facilities.

2.8.1 Functional Testing of Stand Alone Prototype – The objective of this Subtask is to test the ability of the stand alone prototype to automatically detect skin in a range of lighting conditions, both indoors and outdoors. The testing will take place in and around SPARTA offices in Arlington, Virginia. In addition, the ability to pass actionable information, namely the position

[redacted]

of pixels in the imagery that contain skin, to an external system that can process the information to identify and maintain tracks on all dismounted personnel in the camera system's field of view. The main result of this Subtask is the detailed documentation of the camera system's performance and functional capability.

2.8.2 On Sight Demonstration of Detection and Tracking of Dismounts – To exhibit the usefulness of the spectral imager, it will be transported to a Government facility to demonstrate the ability to automatically detect and enable tracking of dismounted personnel in its field of view. The demonstration will include automated spectral detection of dismounted personnel located 10 meters to 400 meters (at a minimum) from the camera and persistent tracking of personnel as they move throughout the local area, including as they move in and out of direct line of sight of the camera. The results of this Subtask are the demonstration and associated demonstration assessment report of the ability of the stand alone spectral imager to collect, process and deliver output in hyperspectral imagery in real time.

2.8.3 On Sight Demonstration of Cueing of High Res Sensor – One of the requirements for Sensors 1 & 2 listed in the BAA is the ability to cue pan/tilt/zoom cameras. The objective of this Subtask is to demonstrate that ability with the spectral imager in a relevant environment. The demonstration will take place at a Government facility and will include the automated cueing of a high resolution sensor (likely a zoom camera) to maintain a persistent track on an individual of the operator's choosing as he moves throughout the camera's field of view. The results of this Subtask are the demonstration and associated demonstration assessment report on the utility of the spectral imager and its ability to deliver actionable data and cue a high resolution sensor.

Assessment Event 2.8.1 – Initial Performance Test: Prior to the on sight demonstration of the function and utility of the spectral imager (Milestone 6), the capability will be tested at SPARTA's facilities in Arlington, Virginia. This assessment event represents a dry run of the camera system performance in a variety of lighting conditions.

Task 2.9 – Initiate Manufacturing – Pending the success of previous Tasks in this effort, there may be a need to move forward and work towards a larger scale production of the camera system. The objective of this Task is to initiate that effort to facilitate the detailed project plan to transition the technology to the Warfighter. SPARTA will initiate dialogues with sensor system manufacturers to explore the capabilities of each to develop the proposed sensor. The main result of this task is a detailed list of options for transitioning the technology to production in large scale. The output from this task will be included in the design documents deliverable.

2.9.1 Identify Vendors for Component Integration on Large Scale – As the program approaches the end of Year 1, effort will be made to explore the transition of the spectral imager to production on a larger scale (100's of items versus 5 or less). The main objective of this Subtask is to survey potential vendors to get accurate cost and effort estimates to manufacture the spectral imager that has the functionality of the prototype. The primary result of this Subtask is a detailed report that identifies the scope of the effort required to mass produce the camera system and a list of vendors that are both able and inclined to manufacture the camera system.

2.9.2 Request Bids – The objective of this Subtask is to formally request proposals from vendors listed in Subtask 9.1. Proposals will detail the Tasks, level of effort and cost to produce upwards of 100 units of the spectral imager. These inputs will be included in the detailed transition plan delivered at the end of Year 1.

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Task 2.10 – Program Management – Continuation of Task 1.10 (described above)

Task 2.11 – Transition to Mobile Platform – The objective of this Task is to demonstrate functionality of prototype developed in Year 1 onto a non-stationary platform. To achieve this effort, the sensor will be configured and/or interfaced with attitude monitoring capability (including a compass and GPS)

Task 2.12 – Integrate and Test with Military System – The objective of this Task is to demonstrate full functionality of the spectral imaging sensor with DCGS-ISR enterprise. Configuring the sensor with appropriate military communications protocol ensures the sensor can be embedded in the net centric environment.

Task 2.13 – Initiate Production – The objective of this Task is to meet with manufacturing organizations to coordinate production of the required number of integrated sensors. This will follow the proposals received in Task 9 of Year 1.

Task 2.14 – Finalize Design (explore hard wired algorithm vs. full CPU) – The objective of this Task is to incorporate feedback from Military personnel and lessons learned during testing and demonstration efforts to finalize the design for the first production-run sensor. During this effort, the concept of replacing the full CPU/on-board processor with a hard wired algorithm, to further reduce size, weight and power requirements, will be explored in detail.

Task 2.15 – Program Management – Similar to the description of Task 10 above, the objective of this Task is to oversee the technical and programmatic success of the proposed effort.

Phase 3 (Option 2) – Sensor Production – The technology transition of the proposed sensor continues in Year 3 of the proposed effort. The delivery of the first generation "mass produced" sensors is expected at this time, and they will be distributed for testing in real-world operating conditions.

Task 3.16 – Manufacture Device – The objective of this Task is to produce the required number of first generation sensors. SPARTA will be the lead systems integrator for the effort.

Task 3.17 – Delivery and Installation of Sensors – The objective of this Task is to deliver and install the sensors to the appropriate Military customer/end user.

Task 3.18 – Testing and Performance Verification – The objective of this Task is to verify the sensors perform as expected under real-world operating conditions.

Task 3.19 – Design for Future Generation – The objective of this Task is to produce the design for the next generation sensor, which will incorporate lessons learned from the first integration cycle and any technological advances that may improve sensor performance and functionality.

Task 3.20 – Program Management – Similar to the description of Task 1.10 above, the objective of this Task is to oversee the technical and programmatic success of the proposed effort.

Year 1 Major Milestones

Milestone 1 – Prototype Final Design CDR – Building on SPARTA's current experience, the final prototype design will be ready for review shortly after kickoff. Milestone 1 will be met upon receiving feedback from ONR following SPARTA presenting its chosen materials design along with support information.

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Milestone 2 – Delivery of Assembled Optical System – Hardware testing will begin once the configured optical components and focal plane array sensors are delivered. This Milestone is significant since it is the point in time at which implementation and integration of dismounted personnel detection can be initiated as well as testing the camera/field-programmable gate array (FPGA) interface of the on-board processor. This Milestone will be achieved following the delivery of the 3 focal plane array camera systems, testing to ensure operability and alignment of each focal plane array, analysis of the spectral bandwidth of each narrow band filter, and demonstration of full camera control.

Milestone 3 – Demonstrate Sensor Interface with Miniature Computer – Before packaging computer components in miniature version, it is critical to test functionality beforehand. This Milestone represents the point in time in which three CCD focal plane array sensors are successfully connected to a breadboard version of the miniature computer. Metrics for success include demonstration of basic sensor control (e.g. image collection, exposure time control, synchronization) and the ability to process images coming off the sensors using the automated skin detection algorithm.

Milestone 4 – Demonstrate Dismount Detection and Tracking – Functionality of automated personnel detection and tracking will show benefit of proposed sensor. This Milestone will be achieved upon the on demonstration of the ability of the spectral imager to perform automated dismounted personnel detection to enable persistent tracking of individuals in the scene as they move throughout (and into and out of sight) the scene. Quantitative metrics for performance assessment will include probability of detection (Pd) and probability of false alarm (Pfa) of dismounted personnel over the duration of the demonstration effort. Success will be achieved with a Pd > 95% and Pfa < 5%.

Milestone 5 – Stand Alone Prototype Functional – Fully operational stand alone prototype of small size, weight and power hyperspectral imager for personnel detection and tracking. This Milestone represents the completed integration of the on-board processor into the camera system. Achievement of this Milestone will be met when full functionality of the camera system is demonstrated, including full camera control, processing of skin detection algorithms and passing of data, including video stream and position of pixels classified as skin.

Milestone 6 – Demonstrate Cueing High Resolution Sensor – Utility of the proposed sensor is demonstrated by passing actionable information to enhance situational awareness. This Milestone will be achieved when the ability to automatically cue a high resolution pan/tilt/zoom camera to maintain a persistent track of an individual with output from the stand alone spectral imager is demonstrated.

Year 2 Major Milestones Please note: Since there appears to be tremendous benefit of the proposed sensor to a wide range of applications/platforms, the out Years 2 and 3 (Options 1 and 2) are structured for the production of the sensor for general application. Details of these efforts and Milestones will be provided during Year 1 once the application and platform of interest are chosen.

Milestone 7 – Demonstration of Prototype on Mobile Platform – Demonstrations in Year 1 keep the position of the stand alone prototype fixed. This demonstration will demonstrate the portability and utility of the spectral imager.

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Milestone 8 – Deliver Hardened Prototype for Integration with Military Platform – The prototype will be configured to be mounted on a Military platform. This Milestone represents the point in time when the sensor integration is complete and full functionality is achieved.

Milestone 9 – Final Design CDR – Experience from transitioning the sensor to a mobile platform will be applied to the final design for the production system. This CDR represents the review of the detailed design and production plan.

Year 3 Major Milestones

Milestone 10 – Delivery of Sensors – Following production of the sensors, they will be delivered and installed on the desired Military platforms. This Milestone represents the completion of that effort.

Milestone 11 – Sensor Performance Verification – Following installation of the sensors, their performance under operational conditions will be verified. The full assessment represents the achievement of this Milestone.

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BIOMETRIC CAPTURE AT A DISTANCE STATEMENT OF WORK

1.1 PROBLEM / INTRODUCTION

Recording iris images of moving subjects at long distances poses several challenges that are addressed by the proposed biometric capture system: resolution and SNR at range, eye-safety, motion, turbulence, and non-cooperativeness. The proposed system addresses these challenges and *will enable biometric capture for moving subjects at long range* that is comparable in performance to current camera systems for stationary subjects at short-range. The proposed baseline camera design includes an eye-safe illuminator, a pair of wide field-of-view (WFOV) cameras, 10"-12" aperture telescope, mechanical gimbal mount, electro-optic subsystems for electro-optic field-of-view (EO FOV) steering and jitter compensation, high speed dynamic focuser, high performance (i.e., sensitivity, resolution) panchromatic high-resolution image sensor, and software for camera control, video tracking, image processing, biometric segmentation and identification.

1.2 DETAILED LISTING OF THE TECHNICAL TASKS/SUBTASKS

Phase 1 (12 months)

1 Requirements Definition.

1.1 Define mission & CONOPS. Working with the Navy and other potential users, the contractor shall identify and prioritize potential biometric missions, identify system and operational constraints, and develop a concept of operations (CONOPs) for each mission.

1.2 Develop system performance requirements. The contractor shall define a baseline of functions and functional performance requirements that must be met in order to accomplish those operations, logistics, support, test, production, and deployment requirements of the proposed biometric capture system.

1.3 Flow down requirements to subsystems. The contractor shall flow down functional and performance requirements to the system, subsystem and component level. Detailed performance requirements for the biometric system shall then be developed, subject to the overall budgetary and schedule constraints of the proposed effort.

2 Design Trades. The contractor shall analyze the detailed performance requirements developed in Task 1.3, and perform a series of design trades to evaluate options presented in this proposal against these requirements.

2.1 Turbulence correction & image pre-processing. The contractor shall perform a series of design trades that evaluate multiple image processing options for turbulence correction. The contractor shall select one approach for further optimization and implementation.

2.2 Radiometry. The contractor shall develop a detailed radiometry model of image signal-to-noise ratio for the proposed biometric capture system.

2.3 Eye safety. The contractor shall develop and model a near–infrared illuminator design that provides necessary image SNR and eye-safety requirements.

2.4 Hardware. The contractor shall evaluate the system-level impact of changes to the baseline optical system design. The contractor shall evaluate and trade design options for the telescope, mechanical gimbal, EO FOV steering, and high-resolution image sensor. The contractor shall evaluate the software and hardware options for fine tracking and jitter stabilization, and down select one approach for optimization and implementation. The contract shall then evaluate and trade design options for the selected approach. The contract shall evaluate and trade design options for the WFOV cameras, stereoscopic range estimation algorithms, and the dynamic focuser.

3 **Preliminary System Design** The contractor shall develop a preliminary system design for the proposed biometric capture system.

3.1 System design. The contractor shall develop the overall system design, showing the functional relationship between subsystems and components. The contractor shall model the performance of system design and evaluate it against safety, reliability, performance, interface, environmental, cost, and schedule requirements. The contractor shall develop preliminary interface control documents to define the physical characteristics of the interfaces and the specifics of the data or signal flow through each interface. The contractor shall develop a summary test plan for characterization and biometric evaluation of proposed system.

3.2 Illuminator. The contractor shall develop a preliminary design for the near-infrared illuminator and control system.

3.3 Agile high-res telescope. The contractor shall develop a preliminary design for the agile telescope, including preliminary specifications for the subsystems and components. Working with optics vendors, the contractor shall develop specifications for the reflective telescope, mechanical gimbal mount, and associated refractive optics. Working with component vendors, the contractor shall develop specifications for the EO FOV subsystem, including the controller and control algorithms. The contractor shall also develop the design for the fine tracking system,
high-res camera, and dynamic focuser.

3.4 WFOV camera & lens. The contractor shall develop a preliminary design for the WFOV camera, lens, and stereoscopic range estimation algorithms.

3.5 Processors & software. The contractor shall develop a preliminary design for the processors, and the integration of algorithms and software routines. The contractor shall develop the design for the EO FOV controller. The contractor shall develop the design for synchronization of the illuminator with the high-res camera. The contractor shall develop the design for coarse tracking controller and interfaces to the telescope gimbal and EO FOV system. The contractor shall develop the design for the fine tracking processor/controller and interfaces to the illuminator and high-res camera. The contractor shall develop a design for the algorithms and software for turbulence correction (i.e., image reconstruction).

3.6 Preliminary Design Review. The contractor shall hold a preliminary design review with ONR and potential users.

4 **Risk Mitigation.** The contractor shall demonstrate mitigation of key risk issues by showing detailed simulation results using validated software models.

4.1 Turbulence correction. The contractor shall demonstrate through simulation reconstruction of turbulence free iris and face images that were blurred due to turbulence. Turbulence conditions that are representative of worse-case operational conditions shall be used.

4.2 Radiometry / eye safety. The contractor shall demonstrate subject tracking using WFOV imagery similar to that expected based on the preliminary design produced in Phase I. The contractor shall capture iris images from 10, 20, and 25 m distance using the proposed illumination scheme and a suitable telephoto imaging system and demonstrate the ability to extract usable iris templates from these images.

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4.3 Agile high-res telescope. The contractor shall demonstrate through simulation diffraction-limited optical performance at the focal plane of a Zemax optical raytrace model of the agile telescope.

Phase 2 (12 months)

5 Critical Design. The contractor shall develop a critical design for the proposed biometric capture system.

5.1 System design. The contractor shall develop a critical system design, providing detailed designs and/or vendor specifications for subsystems and components. The contractor shall provide detailed performance projections with respect to safety, reliability, performance, interface, environment, cost, and schedule. The contractor shall provide detailed interface control documents to define the physical characteristics of the interfaces and the specifics of the data or signal flow through each interface. The contractor shall provide a detailed test plan for characterization and biometric evaluation of proposed system. The test plan shall include detailed plans for iris capture, biometric extraction, and comparison of capture quality for biometric samples at a distance with those collected at short range using commercially available sampling equipment.

5.2 Illuminator. The contractor shall develop a critical design for the near-infrared illuminator and control system.

5.3 Agile high-res telescope. The contractor shall develop a critical design for the agile telescope, including detailed specifications for the subsystems and components. Working with optics vendors, the contractor shall develop detailed specifications for the reflective telescope, mechanical gimbal mount, and associated refractive optics. Working with component vendors, the contractor shall develop detailed specifications for the EO FOV subsystem, including the controller and control algorithms. The contractor shall also develop a detailed design for the fine tracking system, high-res camera, and dynamic focuser.

5.4 WFOV camera & lens. The contractor shall develop a critical design for the WFOV camera, lens, and stereoscopic range estimation algorithms.

5.5 Processors & Software. The contractor shall develop a critical design for the processors, and the integration of algorithms and software routines. The contractor shall develop a detailed design for the EO FOV controller. The contractor shall develop a detailed design for synchronization of the illuminator with the high-res camera. The contractor shall develop a detailed design for coarse tracking controller and interfaces to the telescope gimbal and EO FOV system. The contractor shall develop a detailed design for the fine tracking processor/controller and interfaces to the illuminator and high-res camera. The contractor shall develop a detailed design for the software and processor for turbulence correction and image pre-processing.

5.6 Critical design review. The contractor shall hold a critical design review with ONR and potential users.

6 Fabrication & Test. The contractor shall build and test subsystems and components for the biometric capture system.

6.1 Illuminator. The contractor shall procure and test the laser, power supply and illumination optics.

6.2 Agile high-res telescope. The contractor shall procure and test a 10"-12" aperture reflective telescope, mechanical gimbal mount, associated refractive optics, fine tracking

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camera, high-res camera and dynamic focuser. The contractor shall fabricate and test the EO FOV steering and liquid crystal tilt corrector (if needed) subsystems, and all necessary controllers.

6.3 WFOV camera. The contractor shall procure and test the WFOV cameras and lenses.

6.4 Other processors & software The contractor shall procure and test all necessary processors, and develop or procure software and firmware code for coarse tracking, stereoscopic range estimation, turbulence correction & image pre-processing and biometric extraction.

7 Subsystem Integration & Test. The contractor shall integrate and test the subsystems, while systematically building the brassboard system and confirming subsystem- and system-level functionality.

7.1 Software. The contractor shall test and verify functionality and interoperability of processors and software/firmware code for coarse tracking, stereoscopic range estimation, turbulence correction & image pre-processing and biometric extraction.

7.2 Illuminator & high-res camera synch. The contractor shall integrate and test the illuminator, controller, high-res camera and verify functionality and laser-camera synchronization.

7.3 Dynamic focuser & high-res camera. The contractor shall integrate, align, calibrate and test the dynamic focuser and fine tracking camera, and verify functionality and reproducibility.

7.4 Agile high-res telescope & illuminator. The contractor shall build the agile high-res telescope by starting with the mounted telescope and integrating, aligning, calibrating and testing the following subsystems in sequence: illuminator, EO FOV, fine tracking camera, high-res camera & dynamic focuser, and all necessary controllers and processors.

7.5 System integration. The contractor shall integrate and test the agile high-res telescope and illuminator, WFOV cameras and image pre-processing and turbulence correction software and processors, while systematically building the brassboard system and confirming subsystem- and system-level functionality.

7.6 System functional test. The contractor shall perform a system level functional test and characterize the system performance, comparing it against the critical design projected performance.

8 Biometric Evaluation. The contractor shall perform a detailed and critical evaluation of the biometric capture system.

8.1 Iris capture experiments. The contractor shall execute the iris capture test plan developed in Task 5.

8.2 Biometric extraction. The contractor shall execute the biometric extraction test plan developed in Task 5.

8.3 Comparison of biometric capture quality. The contractor shall execute the biometric comparison plan developed in Task 5.

8.4 System demonstration. The contractor shall perform a live demonstration of the biometric capture system at a contractor facility to ONR and potential users.

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STATEMENT OF WORK

The program will develop two separate standoff biometric sensor systems: one surface mounted and the other free-standing or operator wearable. Each system will include a remote communication package for handless operator control and alerting as required by the CONOPs. We will execute a three-year, four-phase (Phase II, III, IV optional), risk-managed development program with clear metrics and exit criteria in each phase. This SOW is divided into two sections. The first describes some specific technical approaches that will be utilized within the program and the second provides a high level overview of each program phase.

Abbreviations:

APL	Johns Hopkins University Applied Physics Laboratory
MIT	Harvard University - Massachusetts Institute of Technology Division of Health Sciences and Technology
PPI	Prototype Productions, Incorporated
JHU-SOM	Johns Hopkins School of Medicine
Yale	Dr. Charles A. Morgan III (Yale) and Draper Laboratory Team

TECHNICAL APPROACHES

A) Standoff Biometric Sensor Characterization, Signal Processing and Signal Conditioning

The initial research in this area will focus on understanding the operational utility of microwave Doppler-based biometric sensing. In particular, the impact of body aim-points on the signal-to-noise-ratio (SNR) for the heart rate (HR) and respiratory (RESP) signals. Previous pilot studies were conducted using commercial unmodified microwave gunnplexers (24 and 36 GHz) and horn antenna. Figure 1 shows the experimental setup for the pilot studies (subject in a rotating chair with sensors fixed) and the relative signal power in the HR (~1.4 Hz) and RESP (~0.25 Hz) spectral bands derived from analysis of 5 minutes of data at each angle indicated. For this program, we will replicate this experimental setup. Simultaneous measurements are to be made in the head/neck region and mid torso region from the front around to the back. Critical to our program will be to design our system to be robust with respect to signal variability along the torso and head, so as to be tolerant of non-conducting objects on the clothing that produce dead spots. Absorption of microwaves by wet clothing is another factor that can impact performance. We will also pursue signal tracking approaches to ensure high probability of signal acquisition under realistic operating conditions.

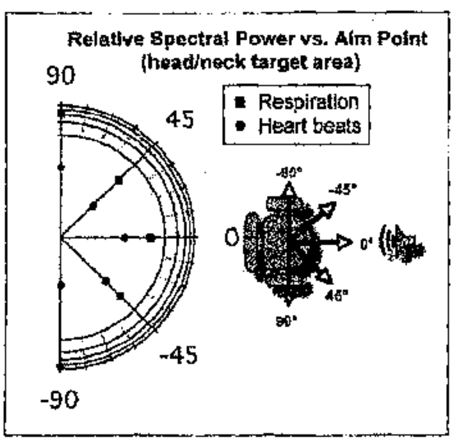

Figure 1. HR and RESP relative signal power around the head/neck region.

We will pursue several digital signal processing approaches to perform the heart beat time series extraction from the standoff sensor data. The first is to use template matching, where we will devise prototypes beat signatures (which may be wavelet

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transform encoded) and execute a fitting procedure based on the physiological constraints imposed by the autonomic nervous system (ANS). The constraint models will be developed by Dr. Cohen's laboratory at MIT. A second approach will be to use multiple sensors aimed at different points on the body and then use fusion algorithms to interleave these beats (based on their SNR or goodness of fit to the templates criterion) to form a composite time series of inter-beat intervals from the sensors. Digital and analog filtering, as well as additional signal conditions schemes to linearize sensor response, will also be used to effect a more consistent heart beat event morphology in the raw waveforms. Finally, we note that the ANS index metrics MIT has developed under prior funded research with APL require only 3 consecutive quality inter-beat intervals to compute. Thus ANS "drop-outs" in a recording from a subject may be tolerable. The tolerance of our mental stress detection to the frequency of ANS index "drop-outs" due to poor heart beat detection episodes will be evaluated as part of our phase I and Phase II effort.

B) <u>Standoff Microwave Sensing: Safety, Power, and Beam Collimation Considerations</u>

Safety issues must be considered as part of the operational methodology for standoff sensing. The U.S. Federal Communications Commission (FCC) provides safety guidelines for use when operating radio frequency transmitters. These regulations set maximum exposure limits based on several factors, including frequency, power density, field strength, and duration of exposure. The FCC policies take into consideration guidelines recommended by the American National Standards Institute (ANSI) as stated in the "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," ANSI/IEEE C95.1-1992, and the National Council on Radiation Protection and Measurements (NCRP), "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86, 1986.

The microwave Doppler motion sensors operate at a low power level and within the K frequency band, typically at 24 or 36 GHz. Since the absorption of the microwave energy and the depth of penetration within human tissue at these frequencies are minimal (primarily reflected at the skin surface), the Specific Absorption Rate (SAR) safety criterion that must be applied to devices that transmit energy is not applicable here, and the only concerns, as stated by the FCC, ANSI/IEEE, and NCRP, are the power density and duration of exposure. As defined by the FCC, the biometric sensors will operate as a "mobile device, which maintains a separation of more than 20 cm between the transmitter and the individual". In this operational environment, designated as the "General Population/Uncontrolled Exposures," the limits for maximum permissible exposure (MPE) are more stringent. Regulations state that the MPE limit in this setting is a power density

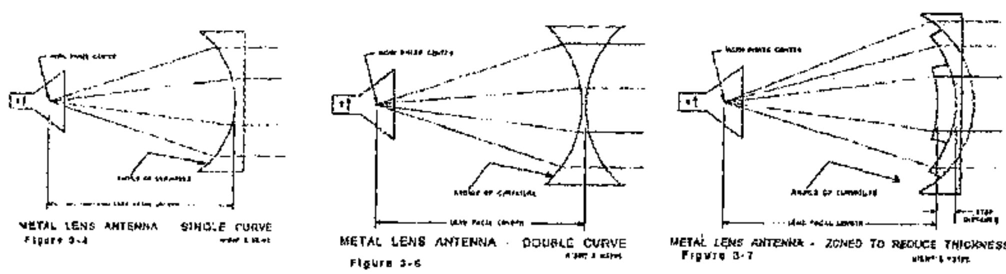

Figure 2. Various configurations for metal lens collimators to focus microwave energy. The collimation can lower battery requirements, and reduce the illuminated field, thereby lowering background motion noise source contributions to the measured cardio-respiratory activity.

of only 1 mW/cm^2 for a continuous exposure of up to 30 minutes.

The critical safety parameters are directly affected by the operating characteristics and geometry chosen for the standoff biometric sensing device; impacting features include transmitter output power, beam-shaping, target illumination area, and source to target distance. Safety concerns impact not only the subject, but also the operator (for operator worn) or interviewer for surface mounted. The transmitter output power has safety considerations that relate directly to the beam shape, power density and exposure times, and energy density. Beam forming can be used as a tool to assist in the control of both the power and energy densities. Several different materials and lens designs can be used to collimate the output beam; some examples are shown in Figure 2 for a metal lens antenna that we will investigate as needed for our applications.

We have performed sample calculations to demonstrate the relationship between the variables of interest (output power, receiver sensitivity, antenna gain, and target area) and to estimate the effect they have on safety levels and operating range. Our results showed that even at the minimum acceptable gain level for successful operation of the microwave gunnplexer, the power densities are orders of magnitude below the required safety level. This means that in order to pose a health hazard, the exposures times would have to be well in excess of 30 minutes for > 5 mW transmitter. For interview setting, where sensors would be located within a few feet, lower power (< 5 mW) sensors will give adequate SNR, thus allowing for prolonged use.

C) Motion Stabilization and Compensation Approaches for Standoff Biometric Sensing

For an operator-worn sensor, the operator's own motion, including pulse and respiration, can have a significant impact on the performance of a remote cardio-respiratory monitor based on microwave Doppler. To address this issue, we will investigate synergistic technical schemes that involve additional sensors to detect, quantify and mitigate the operator motion or vibration for a free-standing sensor. Our baseline approach, which is designed to minimize any risk to device development, will be to incorporate a secondary "referencing" microwave transceiver into sensor package. In order to facilitate signal processing requirements, this transceiver will have a different operating frequency than the primary transceiver used to measure the sensor's motions.

A second approach is slightly more sophisticated and involves additional development risk, but could have potential high payoff in terms of unit cost and performance. In this scheme, the biometric sensor unit will be instrumented with MEMS gyroscopic and accelerometer-based motion sensors. Time series data obtained from these motion sensors will be used to time gate signals received from the subject so that the signal acquisition occurs only when operator motion is below a suitably defined threshold level.

Another hybrid signal gating method will also be considered. In this case, a reference transceiver directed at the operator will be used, not only to characterize the background noise, but also to provide the critical timing information for subject HR and RESP data acquisition. This will be accomplished by signal processing on the secondary transceiver return in order to extract cardio-respiratory information of the operator. This data will be used to establish a cardio-respiratory gating signal for increased signal-to-noise and resolution.

Motion stabilization is a common problem in diverse domains and we plan to extensively leverage proven subsystems and sensors already in use in industry as may be needed for this project. For example, InvenSense, Inc. has developed a dual-axis MEMS gyro that is small, lightweight, and economical that could be used for our signal gating approach. It was designed for use within commercial electronic hand-held devices, in particular, cell phone camera systems, but can be adapted for our purposes. Recent work by Luinge and Veltink published in a study entitled "Measuring orientation of human body segments using miniature gyroscopes and accelerometers" demonstrated concepts for combining gyro and accelerometer technologies that may also be applicable to our operator worn biometric sensors. We will continue to monitor the trade literature for novel stabilization schemes that could augment and improve upon the ideas we have described above.

Finally, non-microwave-based approaches, for example, eye-safe LIDARs have emerged as an alternative method for motion-tolerant standoff biometric sensing. High fidelity, frame-to-frame pixel registration approaches now allow measurements of micro-movements of skin along the face and neck, even while the subject is moving. The downside of this technology is it requires line-of-sight (does not "see" through clothing). This capability facilitates detection of the minute oscillations of skin on the neck reflecting the movements of the carotid arteries. Since LIDARs are highly collimated, the measurements can be made at great distances with minimal background noise from extraneous moving objects within the illumination field - a significant hurdle for microwave-radar based approaches. We will investigate this approach as an complement to a wearable microwave sensor platform for portal, roadblock and related settings.

D) <u>Operator Motion Simulator for the Operator Worn Biometric Sensor Testing</u>

To enable testing of operator motion stabilization and compensation schemes for microwave sensors, PPI will design and manufacture a motion simulator platform as may be required during Phases I and Option Phase II research and development. It will provide programmable displacement and frequency output under computer control. This variable excitation will allow the team to characterize performance of the biometric sensor under simulated operating conditions, which may include periodic movement associated with operator tremor and respiration, in combination with pseudo-random movements associated with rapid head turns or arm motions or vibrations for a free-standing sensor. The team will document a range of frequency and amplitude combinations, which will be fed into the simulator in a laboratory test environment to assess the signal sensitivity to movement and vibration inputs.

E) <u>Fabrication of Alpha, Beta, and Deliverable Prototype Biometric Sensor Systems</u>

PPI will be responsible complete packaged system design for components of the prototype biometric sensors, including internal packaging of the microwave systems and signal processing components, along with internal batteries. JHU/APL will be responsible for providing specific electronic sub-components and the communication and control systems. Other vendors may contribute components as developments warrant. The systems will be hardened to survive specific Mil-STD-810 test methods. PPI will develop conceptual electromechanical designs for subsystems, and will be responsible for integrating subsystems into the sensors design. The critical aspects of a successful implementation will be packaging of all subsystems within a compact lightweight enclosure, and hardening the design to meet environmental requirements.

The system will be capable of running on standalone battery power or plugged into available power sources, with all processing tasks carried out within the device and/or its subsystems.

Environmental hardening per MIL-STD-810F requires tailoring of design and test parameters (see figure 3) and will involve personnel at the program, conceptual and detailed design levels. Test requirements will be developed, and an environmental test plan will be documented. Detailed design decisions flow down from both design and test requirements. Platform environments will be considered when determining shock and vibration limits for transporting the system throughout the supply chain. A test program will then be tailored (see Figure 4) to verify the design has addressed all requirements

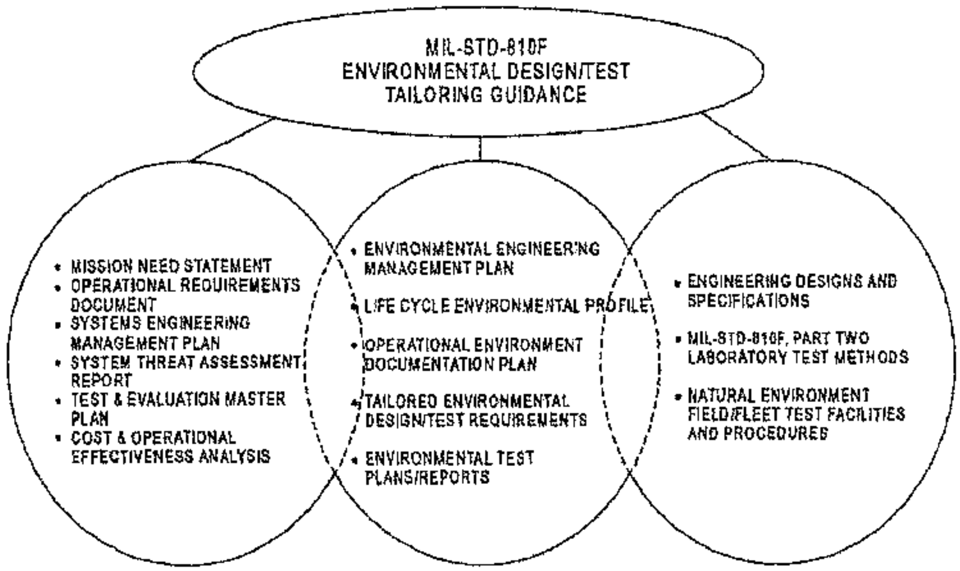

Figure 3. Tailoring design requirements per MIL-STD-810F.

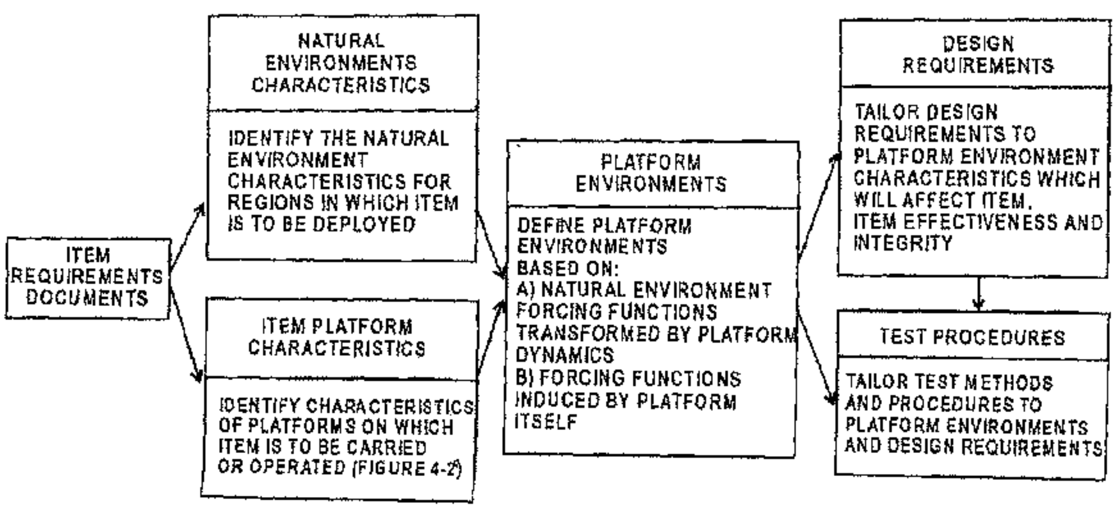

Figure 4. Environmental test program tailoring

F) Mental Stress Characterization Approach

Our hardware development and signal processing approaches will all be geared to providing the highest accuracy covert measurement of mean heart rate, HRV, and RESP. Critical to our concept and CONOPS development is the fact that ANS dynamics (state changes) are known to be associated with psychological challenge and mental stress.

The overarching objectives of the mental stress index development task is to develop algorithms to process heart beat pulse interval data obtained using concealable biometric sensors to obtain autonomic nervous system (ANS) indices that will be able to:

> (1) Measure ambient levels of psychological stress in a given individual.
> (2) Detect changes in psychological stress in a given individual on a time scale of seconds associated with acute stressors such specific stressful questions, deceptive responses to such questions, or other stressors oriented toward eliciting intent.

G) Behavioral Science for TTP Development

In addition to the technical challenges associated with the remote assessment of human physiology, we will address a number of behavioral challenges associated with the assessment of human beings while they are interacting with conspecifics, i.e. interacting each other. Some of these challenges are directly related to validating specific hypotheses concerning the relationship between human stress responses (physiological indices of the ANS) and human cognition (i.e. mindset, intent, perception of situation, etc..), as well as the relationship of these within a particular cultural setting (i.e. ethnicity, language, religion, etc..). For the latter, our team will engage a cultural anthropologist in order to ensure that laboratory setting results will translate into field settings of interest.

Over the past 40 years, numerous pre-clinical and clinical scientific studies have provided robust evidence that states of arousal and alarm (whether measured by brain waves, hormones or physiology) are directly related to the manner in which the animal or person perceives events within their particular situation. As such, the behavioral science work in this project will focus on the assessment of human arousal within specific emotional, social and cultural contexts. Specifically, this means we will test: A) how well assessments of human arousal can be used to distinguish between positive, neutral and negative emotional subjective states; B) how well assessments of arousal can distinguish between states of emotional distress associated with non-violent fear, anxiety and alarm and those associated with mal-intent, violence and aggression; C) how well covertly acquired indices of arousal may contribute to an assessment of emotional states and intent when conducted under diverse operational conditions (witting, unwitting, non confrontational, confrontational, conversational, interrogatory, etc...); and finally D) how well covert assessments of physiology may inform interactions between US personnel and people of non-American cultures who do not speak English (for example, Arabic speaking cultures).

To accomplish these goals, our work is divided into two distinct, synergistic efforts.

The initial research effort, to be conducted in Program Phase I will involve testing the primary hypothesis about whether and to what extent states of arousal can meaningfully distinguish stress

[redacted]

differing in emotional valence (positive or negative emotional "charge"). This work be conducted within a traditional laboratory setting (Draper Laboratory) and involve the physiological assessment of arousal under non-stressful conditions as well as under conditions of stress that entail a positive valence (i.e. high stakes gambling) and those associated with a negative valence (i.e. a polygraph examination by Security in a deception study). In program Phase II, we also aim to test how well such distinctions can be made in individuals who have been exposed to very high stress (i.e. interrogation stress during mock-captivity at Survival School). This type of data will inform us about how well meaningful distinctions of human arousal can be made within a background of detention stress. We will also work actively with the customer within the Special Operations community to develop testing paradigms based on information from the customer about the situations, cultures, and people of interest. These efforts to be executed in Phase I and Option Phase II of the program will produce a human study design with specific TTP concepts that will be tested in the subsequent phases of the program.

In the 2nd research effort, we will execute human studies within the contexts of interest (i.e. types of settings in which conversations, interviews or interrogations might occur). This will permit an assessment of whether the data obtained from the covert assessment technology, in concert with other behavioral cues, is sufficient to function within a non-laboratory environment. In addition, this phase of testing will provide information about future packaging and communications requirements within the contexts and cultures of interest. As noted above, and because social and cultural factors shape human perception and emotional responses to events, in these studies we will test how well the methods can be used when assessing interviews conducted through the use of an interpreter and within a specific cultural context. In the latter program phases we use the priorities provided to us by the operational SOCOM group and work directly with cleared foreign national culture experts and relevant anthropologists in order to assess efficacy of this technology within settings closely approximating real world conditions. As in previous studies (Dr. Morgan) and work with the Special Operations community, we will include Subject Matter Experts in the non-American populations (anthropologists) as well as vetted foreign nationals from the regions and social classes of interest.

Further, and directly relevant to operational settings, it is imperative that we test whether it is possible to distinguish between the type of arousal noted in a person who is fearful of, and alarmed by interacting with US personnel and the type of arousal noted in a person who harbors feelings of aggression and mal-intent toward US personnel. Whereas the arousal in one person reflects their distress, that in the second may be associated with the intent to do harm to US personnel or others. At the present time, the distinctions between such states of human arousal await empirical verification.

Finally, we note that the initial research effort described above will address a fundamental behavioral science question with respect to the assessment of human arousal and stress responses, that is, to what degree, states of human arousal associated with Eustress [i.e., positive-valence emotions such as nervous excitement or anxiety that one might experience while anticipating or waiting for something highly desired] can be distinguished from states of arousal associated with Distress [i.e. negative valence emotions such as fear, alarm or anxiety of the type a person might experience when anticipating or confronting some event or experience that entails loss, pain, suffering or other types of negative consequences]. Information from non-human and human animal studies provide evidence that is reasonable to speculate that distinctions between the subjective states of Eustress and Distress can be detected through the assessment of human physiology. However, to date, this hypothesis has not been directly tested.

TASK DESCRIPTIONS OVERVIEW

Phase I Tasking Overview

Our first task in phase I will be to perform a preliminary requirements analysis. We will then initiate design and fabrication of modular breadboard prototype standoff biometric sensors. The sensors will be tested in a laboratory setting, and in some case validated in routine sleep studies conducted at the Johns Hopkins Sleep Disorders Center, where patients are monitored using gold-standard electrocardiographic and respiratory sensors. Digital signal processing algorithms will be developed and refined to optimize performance during this phase. Various possible system configurations will be evaluated to enable comparison of the performance of the alternative designs against the requirements. During this phase, an operator motion simulator platform will be fabricated as may be required. We described above several technical approaches that will be investigated to account for and counteract this operator "noise" or platform noise. We will also perform preliminary testing of sensors in a mock interrogation test bed setting.

In parallel with hardware development, mental stress detection algorithms will be developed and validated against archival polygraph data, available at APL through its prior extensive work for the DoD polygraph Institute. Prior work by APL and MIT demonstrated that polygraph exams themselves are good models for mentally stressful encounter that is detectable via changing ANS metrics. Importantly, the HR data obtained during polygraph is from a pressure cuff that does not directly measure the heart's electrical activity, but the pulse, which is a noisier source for determining ANS state, but is what can be measured by covert means using standoff sensing. The APL polygraph data will also be augmented with data obtained from an on-going credibility assessment study being conducted in the testbed environment referenced above. In this study HR will be

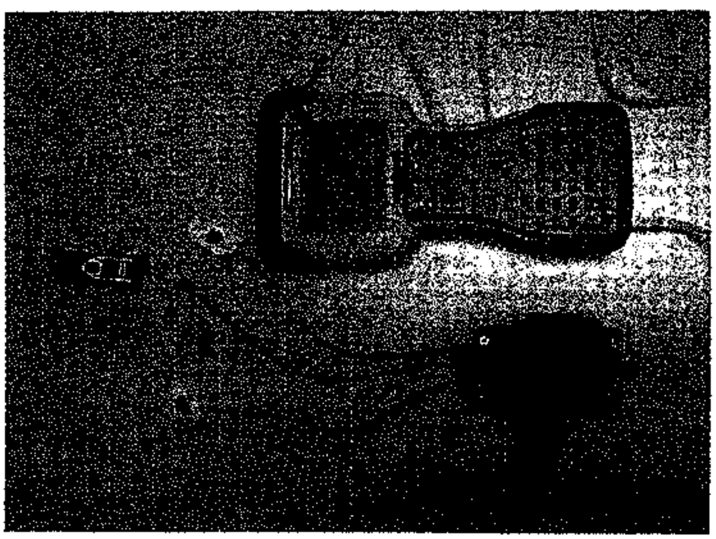

Figure 5. The PCASS system will be used for pulse interval data collection in the field by a SOCOM team. Labeled data will be provided to the APL and MIT for further refinement and validation of ANS state change detection algorithms for realistic conditions.

combined with other behavioral cues by interviewers in a realistic setting as part of an overall credibility assessment. Dr. Morgan (Yale/Draper) will provide these data to APL and MIT to test ANS state change algorithms and evaluate mental stress detection in this setting. These data will help set performance targets for the stress detection algorithms, both when used alone and in combination with other modalities available to interviewers. Importantly, both polygraph (pulse) and cardio-respiratory data from this test bed can be "blurred" by the estimated measurement noise and errors of the standoff biometric sensing devices to determine the tolerances of the mental stress detection algorithms to sensor noise.

In Phase I, we will also conduct behavioral science experiments regarding elicitation of states of arousal in the test bed at Draper Laboratory and consult with the SOCOM customer to develop initial TTP concepts for covert biometric sensor use to help set the performance requirements for the developed sensor systems in the settings of specific CONOPSs. The detailed hypotheses to be tested and approaches are described above. The team under Dr. Morgan, will lead this effort with participants from Draper Laboratory. The Phase I and Phase II goal for this team is to obtain fundamental data on triggers and classes of ANS arousal. To supplement the data we obtain from Draper from the mock interrogation setting, APL will provide a SOCOM team two portable PCASS polygraph systems, which also function as HR data collection devices. PCASS was

<u>Phase I Tasking (Basic Period, 6 months)</u>

Task
1a- Standoff Sensor Development
Preliminary requirements capture
Preliminary design review
Initiate modular Breadboard design and fabrication
Digital signal processing algorithm development
Data analysis
Initiate breadboard test and evaluation
Program progress review (go, no-go) *CRITICAL MILESTONE*
1b- Motion Simulator Test Platform Development
1c- Mental Stress Index Development
1d- TTP Concepts Development
Behavioral psychology experiments
Interfacing with SOCOM customer
1e- Alpha Prototype Preliminary Design
1f- Program Management
Present at program reviews for ONR sponsor
Develop and execute technology transition agreement (TTA)
Financial reporting at sponsor-specified intervals

developed by APL, includes APL algorithms and is now available commercially (system is shown in Figure 5 above). The SOCOM team will use these devices in the field in real settings, label the data, and provide it to our program for analysis. It is anticipated that field data will be made available to our team from SOCOM in Optional Phases II-IV of the program. The settings in which these data will be obtained are CLASSIFIED, but we will try to arrange for the data itself to be unclassified.

Phase I will conclude with a go/no-go status review with the ONR sponsor, which will report on breadboard prototype sensor development and test data, preliminary Alpha prototype design, mental stress index development, and early findings from the behavioral psychology elements focusing on TTP development.

<u>**Phase I Deliverables**</u>:

Task 1a

1) Breadboard standoff biometric sensors development status report (briefing materials)

Task 1b

2) Operator motion simulator platform development (briefing materials)

Task 1c

3) Mental stress index development progress report (briefing materials)

Task 1d

4) Behavioral psychology experiments progress report (briefing materials)

Task 1e

5) Preliminary Alpha prototype sensors design (briefing materials)

Task 1f

6) Financial reports at sponsor-specified intervals
7) Technology transition agreement (TTA)
8) Program progress review (briefing materials)

<u>**Phase II (Option 1, 1 Year)**</u>

In Phase II, we will complete fabrication of the modular breadboard sensors and characterize their performance. Mental stress index development will continue and new TTP concepts will be further evolved based on continued analysis of behavioral stress data. These data will then set sensor performance requirements (based on the assumption that the covert biometrics sensors will augment other non-contact behavioral cues). Laboratory data informing TTP concepts will be supplemented in Phase II by field data provided by SOCOM obtained using the new PCASS portable polygraph system in a relevant setting. During this phase, the TTP research will inform the design of a prospective human study to test new TTP concepts that will be initiated following IRB approval. In Phase II, we will also perform an analysis of alternative system designs against performance targets for selected CONOPs as informed by the evolving TTP concepts. Following discussion of this analysis with the sponsor, standalone, final designs for the alpha prototype sensor systems will be executed, followed by Preliminary and Critical Design Reviews. Fabrication of the Alpha prototypes, including communication and control elements, will then be initiated. Phase II will conclude with a program status review, which will include a go/no-go decision for completion of the Alpha prototype systems and continuation of the human studies in Phase III.

ATTACHMENT NUMBER 1, "STATEMENT OF WORK"

1. Statement of Work

1.1 Statement of Work Tasking

This self-standing SOW contains no proprietary restrictions. It consists of a detailed listing of the technical tasks & subtasks organized into 7 high-level tasks. This SOW identifies the product that results from each task/subtask and identifies metrics that will be met as a result of the task/subtask.

Task 1 constitutes approximately the first 6 months of effort and consists of system engineering and requirements analysis to guide subsequent design efforts. Task 2 is estimated to be 12 months in duration and includes development and demonstration of key subsystem elements to gain insight into expected turbulence conditions for the specific collection geometries of interest. Task 2 also includes initial development of the brassboard sensor. Task 3 is estimated to be 12 months in duration and includes completion of the brassboard sensor, including integration, testing, and demonstration at our GDAIS facility in Ypsilanti, MI. Task 3 also includes initial development of the prototype sensor system and integration of the network interface and control codes. Task 4 is estimated to be 6 months in duration and includes integration, testing, and demonstration of the prototype sensor at GDAIS and user testing coordinated and conducted by NRL Stennis.

Task 5 is estimated to be 6 months in duration and addresses the requirements and initial design of the motion detection and cueing algorithms. Task 6 is estimated to be 12 months in duration and includes development and initial testing of the motion detection and cueing algorithm. Task 7 is estimated to be 12 months in duration and addresses the final implementation, integration into the prototype, and test of the motion detection and cueing capability.

1.1.1 Task 1 – System Requirements and Architecture/Subsystem Design SOW

1.1.1.1 Program Management

The contractor shall use proven program and subcontract management practices to attain the technical, cost, and schedule goals of the Persistent Sentinel program. The contractor shall conduct internal technical interchange meetings to facilitate performance on the program. The contractor shall conduct a review at the conclusion of the task to be held at ONR in Arlington, VA. Performance metrics for this task include cost, schedule, and CDRL satisfaction performance.

1.1.1.2 System Requirements Development

The contractor shall develop system requirements necessary for the Persistent Sentinel sensor to provide best possible utility for expeditionary force tactical users. The contactor shall organize and document the requirements. The product of this effort will be a System Requirements Document. This effort will be led by GDAIS, with support from NRL Stennis (particularly tactical user inputs). Performance metrics for this task include completion of the System Requirements Document and the number of requirements it includes.

1.1.1.3 System Architecture Development

The contractor shall develop a system architecture for the Persistent Sentinel sensor which maximizes satisfaction of requirements. The product of this effort will be a System Definition Document which defines the system architecture and allocates performance requirements to the various subsystems. Analyses required to support architecture trades, requirements flowdown and performance predictions shall be performed. Performance metrics for this task include completion of the System Definition Document and the expected performance against requirements.

1.1.1.4 Opto-mechanical Subsystem

The contractor shall design the opto-mechanical subsystem. Design trades and performance analyses shall be performed as required to verify that the design satisfies allocated requirements. Key components may be evaluated to verify performance and reduce risk. The product of this task is the Opto-Mechanical Subsystem Design Document. Performance metrics include completion of the design document and the predicted performance against allocated requirements (e.g., resolution, field of view, size/weight/power).

1.1.1.5 Processor Subsystem

The contractor shall design the processor subsystem. Design trades and performance analyses shall be performed as required to verify that the design satisfies allocated requirements. Key components may be evaluated to verify performance and reduce risk. The product of this task is the Processor Subsystem Design Document. Performance metrics include completion of the design document and the predicted performance against allocated requirements (e.g., data rate/throughput, predicted algorithm runtimes, size/weight/power).

1.1.1.6 Algorithm and Software Subsystem

The contractor shall develop the processing algorithms and perform the software design. Algorithm components shall be prototyped and tested as required to verify that the algorithm performance satisfies allocated requirements. Key components may be evaluated to verify performance and reduce risk. The product of this task is the Processor Subsystem Design Document. Performance metrics include completion of the design document and the predicted performance against allocated requirements (e.g., data rate/throughput, predicted algorithm performance in terms of facial recognition and motion detection performance).

1.1.2 Task 2 – Subsystem Development & Test SOW

1.1.2.1 Program Management

The contractor shall use proven program and subcontract management practices to attain the technical, cost, and schedule goals of the Persistent Sentinel program. The contractor shall conduct internal technical interchange meetings to facilitate performance on the program. The contractor shall conduct a mid-term program review and an end-of-task review at the conclusion of the task. The mid-term program review is anticipated to be

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held at the GDAIS facility in Ypsilanti, MI and the end-of-task review at ONR in Arlington, VA. Performance metrics for this task include cost, schedule, and CDRL satisfaction performance.

1.1.2.2 System Requirements and Architecture Update

The contractor shall update the system requirements to incorporate any relevant new information. The product of this effort will be an updated System Requirements Document. This effort will be led by GDAIS, with support from NRL Stennis. Performance metrics for this task include completion of the updated System Requirements Document and the number of updated requirements.

1.1.2.3 Initial Sensor Development

The contractor shall begin development of an opto-mechanical subsystem for the brassboard sensor system meeting the allocated requirements. This subsystem shall include optical tube assemblies and/or lenses, cameras, including any associated mounting and pointing hardware for both the wide field and narrow field sensors. The product of this task is the partially completed opto-mechanical subsystem. Performance metrics for this task include measured scene resolution, field of view, and camera resolution (number of pixels) and frame rate for the subsystem.

1.1.2.4 Initial Processor Development

The contractor shall begin development of the processor subsystem meeting the allocated design requirements. The product of this task is the partially completed and tested processor subsystem. Performance metrics include performance against allocated requirements, frame rate, latency, size/weight/power.

1.1.2.5 Initial Algorithm and Software Development

The contractor shall begin development and test the processing algorithms and software. The product of this task is an initial implementation of processing software, along with necessary control, data handling, and interface software. Performance metrics include performance against allocated requirements (e.g., data rate/throughput, algorithm runtime performance in terms of facial recognition and motion detection performance).

1.1.3 Task 3 – Brassboard Development & Test SOW

1.1.3.1 Program Management

The contractor shall use proven program and subcontract management practices to attain the technical, cost, and schedule goals of the Persistent Sentinel program. The contractor shall conduct internal technical interchange meetings to facilitate performance on the program. The contractor shall conduct a mid-term program review and an end-of-term review at the conclusion of the task. The mid-term program review is anticipated to be held at the GDAIS facility in Ypsilanti, MI and the end-of-term review at ONR in Arlington, VA. Performance metrics for this task include cost, schedule, and CDRL satisfaction performance.

1.1.3.2 Complete Brassboard Sensor Development

The contractor shall develop an opto-mechanical subsystem for the brassboard sensor system meeting the allocated requirements. This subsystem shall include optical tube assemblies and/or lenses, cameras, including any associated mounting and pointing hardware for both the wide field and narrow field sensors. The product of this task is the completed and tested opto-mechanical subsystem. Performance metrics for this task include measured scene resolution, field of view, and camera resolution (number of pixels) and frame rate for the subsystem.

1.1.3.3 Complete Brassboard Processor Development

The contractor shall develop the processor subsystem meeting the allocated design requirements. The product of this task is the completed and tested processor subsystem. Performance metrics include performance against allocated requirements, frame rate, latency, size/weight/power.

1.1.3.4 Complete Brassboard Software & Algorithm Development

The contractor shall develop and test the processing algorithms and software. The product of this task is the software implementing the processing algorithm, along with necessary control, data handling, and interface software. Performance metrics include performance against allocated requirements (e.g., data rate/throughput, algorithm runtime performance in terms of facial recognition and motion detection performance).

1.1.3.5 Brassboard Integration and Test

The contractor shall integrate and test the overall Persistent Sentinel brassboard system, including opto-mechanical, processor, and software subsystems. Performance of the integrated system shall be evaluated with respect to system requirements. The product of this task is the integrated and tested system. Relevant performance metrics include integration and test results.

1.1.3.6 Brassboard Data Collections and Analysis

The contractor shall use the Persistent Sentinel brassboard sensor system to collect demonstration data. The collected data shall be analyzed to measure system performance with an emphasis on assessing tactical user utility and on identifying areas for further performance improvements. This effort will be led by GDAIS, with support from NRL Stennis. The product of this task is the collected data and analysis results.

1.1.3.7 Requirements and Architecture Update for Prototype

The contractor shall update the requirements to incorporate any relevant new information and update the system architecture as necessary to accommodate the requirements changes. The product of this effort will be an updated System Requirements Document. This effort will be led by GDAIS, with support from NRL Stennis. Performance metrics for this task include completion of the updated System Requirements Document and the number of updated requirements.

1.1.3.8 Networking and Messaging for Prototype

The contractor shall implement a network interface to the Persistent Sentinel sensor to provide interoperability with networked tactical users. This interface shall enable remote command and control of the sensor via the network, including access to stored data. The interface shall support messaging of events detected by the sensor (e.g., motion events). The product of this task is the networking and messaging software integrated into the Persistent Sentinel sensor system.

1.1.3.9 Algorithm Refinement for Prototype

The contractor shall refine the algorithms and control software to optimize sensor system performance with respect to requirements. The product of this task is the processor software for the prototype system. Metrics include performance against allocated requirements (e.g., data rate/throughput, predicted algorithm performance in terms of facial recognition and motion detection performance).

1.1.4 Task 4 – Prototype Development & Test SOW

1.1.4.1 Program Management

The contractor shall use proven program and subcontract management practices to attain the technical, cost, and schedule goals of the Persistent Sentinel program. The contractor shall conduct internal technical interchange meetings to facilitate performance on the program. The contractor shall conduct a final review at the conclusion of the task to be held at ONR in Arlington, VA. Performance metrics for this task include cost, schedule, and CDRL satisfaction performance.

1.1.4.2 Prototype Integration and Test

The contractor shall integrate and test the overall Persistent Sentinel prototype system, including opto-mechanical, processor, and software subsystems, including the network command and control interface. Performance of the integrated system shall be evaluated with respect to system requirements. The product of this task is the integrated and tested system. Relevant performance metrics include integration and test results to be assessed with respect to requirements.

1.1.4.3 Test Planning

The contractor shall plan field tests and user demonstrations to enable assessment of the system performance in situations relevant to tactical users. This effort will be led by NRL Stennis, with support from GDAIS.

1.1.4.4 Field Tests and User Demonstrations

The contractor shall conduct field tests and user demonstrations of the prototype Persistent Sentinel sensor system. Results will be analyzed to assess system performance. The product of this task will be the demonstration results and data, including measured facial recognition performance and motion detection performance.

1.1.5 Task 5 – Motion Detection Requirements & Algorithm Design SOW

1.1.5.1 Program Management

The contractor shall use proven program and subcontract management practices to attain the technical, cost, and schedule goals of the Persistent Sentinel program. The contractor shall conduct internal technical interchange meetings to facilitate performance on the program. The contractor shall conduct a review at the conclusion of the task to be held at ONR in Arlington, VA. Performance metrics for this task include cost, schedule, and CDRL satisfaction performance.

1.1.5.2 Motion Detection Algorithm Design

The contractor shall establish requirements for a motion detection and cueing capability for the Persistent Sentinel sensor and develop an initial algorithm design.

1.1.6 Task 6 – Motion Detection Algorithm Development SOW

1.1.6.1 Program Management

The contractor shall use proven program and subcontract management practices to attain the technical, cost, and schedule goals of the Persistent Sentinel program. The contractor shall conduct a mid-term program review and an end-of-task review at the conclusion of the task. The mid-term program review is anticipated to be held at the GDAIS facility in Ypsilanti, MI and the end-of-task review at ONR in Arlington, VA. Performance metrics for this task include cost, schedule, and CDRL satisfaction performance.

1.1.6.2 Motion Detection Algorithm Development

The contractor shall develop the motion detection algorithm and test the performance against the requirements established in task 5.

1.1.7 Task 7 – Motion Detection Implementation & Test SOW

1.1.7.1 Program Management

The contractor shall use proven program and subcontract management practices to attain the technical, cost, and schedule goals of the Persistent Sentinel program. The contractor shall conduct internal technical interchange meetings to facilitate performance on the program. The contractor shall conduct a mid-term program review and an end-of-task review at the conclusion of the task. The mid-term program review is anticipated to be held at the GDAIS facility in Ypsilanti, MI and the end-of-task review at ONR in Arlington, VA. Performance metrics for this task include cost, schedule, and CDRL satisfaction performance.

1.1.7.2 Motion Detection Implementation, Integration, & Test

The contractor shall implement the motion detection algorithm developed in task 5 and integrate the capability into the prototype. The integrated capability will be tested with respect to the performance requirements established in task 5.

1.2 Deliverables

The deliverable items for the Persistent Sentinel program are identified in Figure 1 by the task period in which they will be delivered. Deliverables from the first task include the results of system requirements development work by NRL and GDAIS in the System Requirements and Definition document. Quarterly status reports summarizing technical and financial performance will be provided throughout the program. The Task 2 report will summarize the predicted performance and results of subsystem breadboard testing. The primary deliverable from Task 3 is the brassboard sensor system with wide field of view (WFOV) and narrow field of view (NFOV) sensors along with the resolution enhancement and motion detection processing system. The Task 3 report will summarize the findings and test results, including facial recognition and motion detection demonstration results and a description of the processing algorithms. Test data collected from scenarios of interest will also be delivered.

The advanced prototype of the Persistent Sentinel sensor system is the primary deliverable resulting from Task 4 efforts. The Task 4 report will summarize the findings and results of user testing, including facial recognition and motion detection demonstration results. Test data collected will also be delivered. A technical report describing the SOA network services interface will be developed and delivered.

Development and implementation of algorithms for motion detection and cueing of the optical sensor will be addressed in tasks 5, 6, and 7. The requirements, system architecture modifications, and initial design of the motion detection algorithms will be addressed in Task 5. Task 6 is scheduled to last for 6 months. The estimated one-year Task 7 efforts cover the development and testing of the motion detection and cueing algorithm using data from the subsystem breadboard developed in option 1. The final implementation of the motion detection and cueing functionality, including integration and test of the capability, will be addressed during Task 7 efforts.

Figure 1. Persistent Sentinel Program Deliverables by Task

Delivered Item	Task 1	Task 2	Task 3	Task 4
System Design and Prototype Hardware	System Requirements and Definition Document	n/a	Brassboard sensor system with WFOV and NFOV sensors, processor supporting resolution enhancement, motion detection, and fine-resolution video imagery	Advanced sensor prototype with SOA services interface
Technical Reports*	n/a	Initial Camera Requirements Specification*; Task 2 report, including Predicted Performance	Task 3 Report, including processing algorithm descriptions	Task 4 report, incl. description of SOA Services; Final Camera Requirements Specification
Test Data	Engineering Test Data	Engineering. Test Data from subsystem breadboards	Scenario Test Data	User-Demonstration Test Data
Demonstrati on Results	n/a	Face-recognition and resolution-target results for scenarios of interest;	Measured resolution performance as a function of range and terrain on resolution targets; Automatic face recognition results as a function of range and terrain	Autonomous motion-detection cueing fine-resolution pan-tilt camera with capability to perform facial recognition, identification, and tracking
Program Management	Quarterly technical and financial status reports	Quarterly technical and financial status reports	Quarterly technical and financial status reports.	Quarterly technical and financial status reports.

*GDAIS will develop and deliver a camera requirements specification in order to facilitate integration of the Persistent Sentinel algorithms with legacy cameras and systems. These legacy systems may need to be modified or upgraded to be compatible with the algorithms and the specification will define the essential design parameters required by the algorithms. An initial version of the specification will be delivered at the completion of Task 2 work. The final specification will be delivered at the completion of Task 4 work.

[redacted]

Delivered Item	Task 5 Motion Detection	Task 6 Motion Detection	Task 7 Motion Detection
Technical Reports	n/a	Preliminary motion-detection performance assessment	Motion detection final report, incl. final motion-detection performance assessment
Test Data	n/a	Moving target test data	Moving target test data
Demonstration Results	n/a	Motion-detection and cueing initial demonstration results	Motion-detection and cueing final demonstration results
Program Management	Quarterly technical and financial status reports	Quarterly technical and financial status reports	Quarterly technical and financial status reports